Optical Telescope Assembly

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Telescope: Overview

- Science Driven Requirements
- Main R&D Issues
- Status
- R&D Schedule
- R&D Manpower
- R&D Costs
- R&D Management
- Summary

Telescope: Science Driven Requirements

- **Light Gathering Power**
  - must measure SNe 4 magnitudes fainter than 26 magnitude peak
  - require SNR of 50:1 at peak brightness
  - presence of zodiacal light foreground radiation
  - time-on-target limited by revisit rate & number of fields
  - spectroscopy demands comparable time-on-target
  - requires geometric diameter ~ 2 meters
- **Angular resolution**
  - signal to noise ratio is driver
  - diffraction limit imposes upper bound
  - Airy disk at one micron wavelength is 0.12 arcseconds FWHM
  - geometric blur must be kept well below this limit.
- **Field of View**
  - determined by required supernova discovery rate
  - volume of space is proportional to field of view
  - one square degree area will deliver the requisite discovery rate
- **Wavelength Coverage**
  - 0.35 to 1.7 microns requires all-reflector optical train

Telescope: Main R&D Issues

- Need to refine performance specifications
- Need to understand & communicate tolerances
- Need to prepare draft Interface Control Documents
  - — optical
  - — thermal
  - — mechanical
  - — electrical
- Need to assess risks and take steps to minimize them
- Need to perform trade studies (outlined below)
- Critical Path: Need to explore ways to implement long-lead mirror procurement
- Need to begin development of the OTA requirements document for potential bidders

Telescope: History

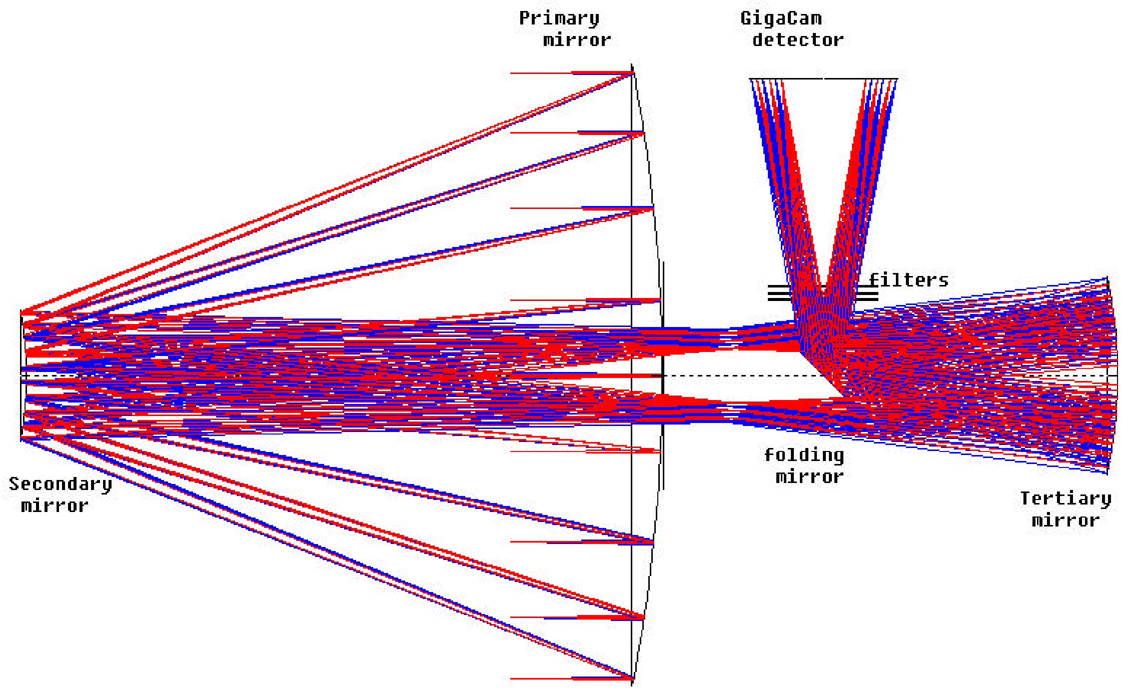
- **Wide-field high-resolution telescopes are NOT new**
  - —Schmidt cameras (1930 to present)
  - —Field-widened cassegrains, Gascoigne (1977-); SDSS
  - —Paul three-mirror telescopes (1935) and Baker-Paul
  - —Cook three-mirror anastigmats (1979)
  - —Williams TMA variants (1979)
  - —Korsch family of TMAs (1980)
  - —Angel-Woolf-Epps three-mirror design (1982)
  - —McGraw three-mirror system (1982)
  - —Willstrop "Mersenne Schmidt" family (1984)

Telescope: Downselection

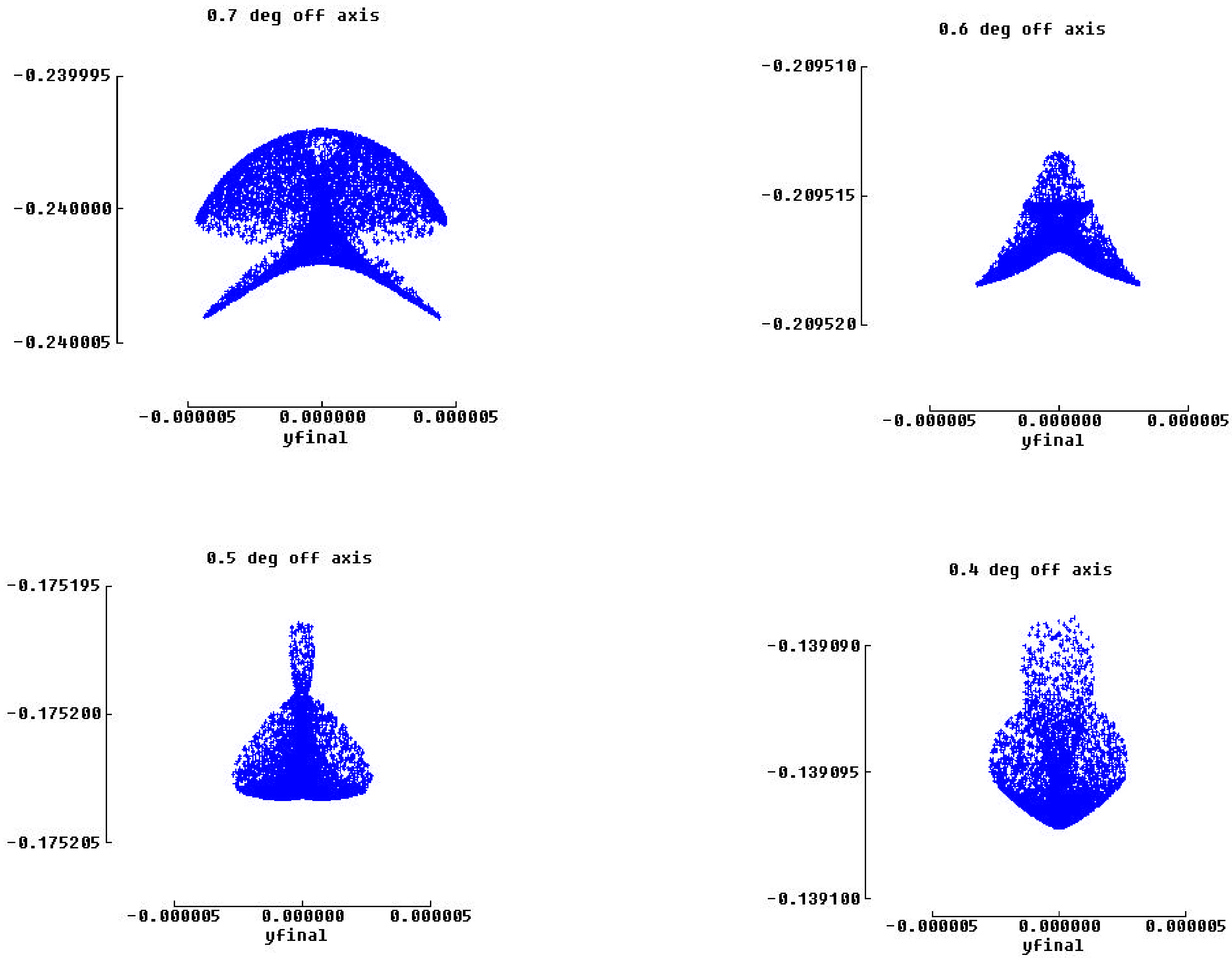
- **1999-2000: Suitability Assessments**
  - —off-axis designs attractive but unpackagable; rejected
  - —four, five, and six-mirror variants explored; rejected
  - —eccentric pupil designs explored; rejected
  - —annular field TMA concept discovered & developed
  - —TMA43 (f/10): satisfactory performance but lacked margins for adjustment
  - —TMA55 (f/10): improved performance, shorter pri-sec, margins OK
  - —TMA59 (f/15): same but with longer focal length

Telescope: Status

- **Baseline Optical System: Annular Field TMA**
  - — prolate ellipsoid concave primary mirror
  - — hyperbolic convex secondary mirror
  - — prolate ellipsoid concave tertiary mirror
  - — small flat folding mirror
  - — flat focal plane
  - — delivers < 0.04 arcsecond FWHM geometrical blur over annular field 1 sqdeg
  - — adaptable to range of focal lengths 20 meters through 30 meters
  - — provides side-mounted detector location for best detector cooling



Telescope: Performance

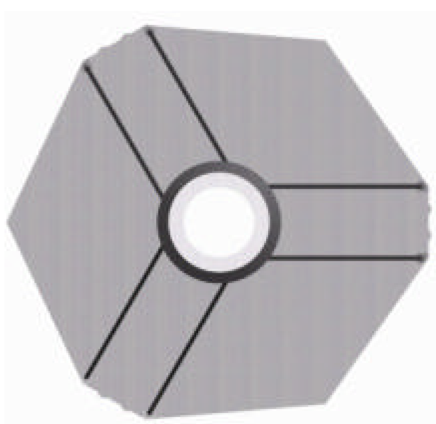


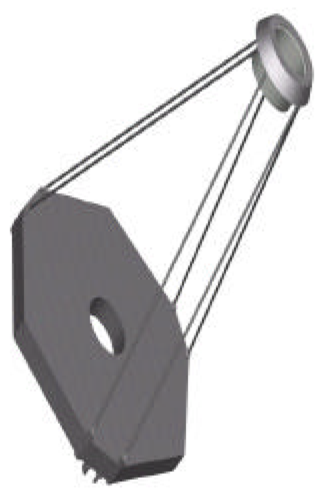
Telescope: Status

- OTA mechanical concepts developed during pre-PhaseA
  - —secondary mirror support metering structure concepts
  - —FEM modal resonances explored for most promising variants
  - —tertiary mirror support metering structure concepts developed
  - —primary mirror strongback structure concepts
  - —primary mirror attachment methods discussed

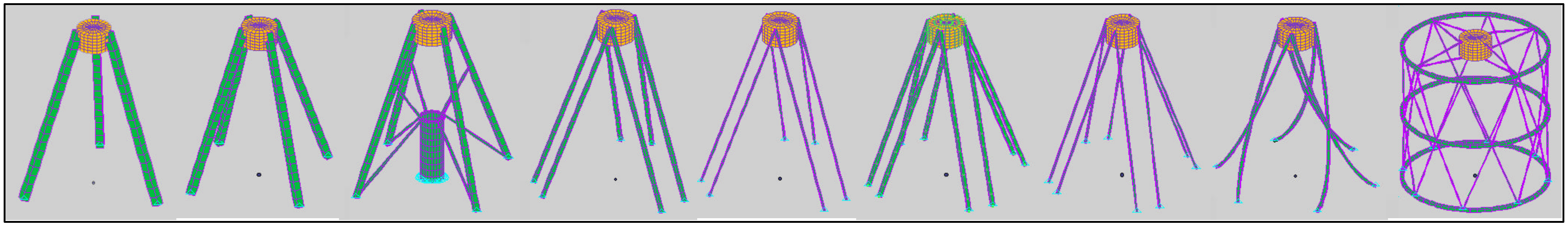
Secondary Metering Structure

- **Key requirements:**
  - — **Minimize obscuration (<3.5%) & interference spikes**
  - — **Dimensional stability**
  - — **35 Hz minimum fundamental frequency**
- **Baseline design: hexapod truss with fixed end**
  - — **Simple design with low obscuration (3.5%)**
  - — **6-spiked diffraction pattern**
  - — **Ø 23 mm by 1 mm wall tubular composite (250 GPa material) struts with invar end-fittings.**





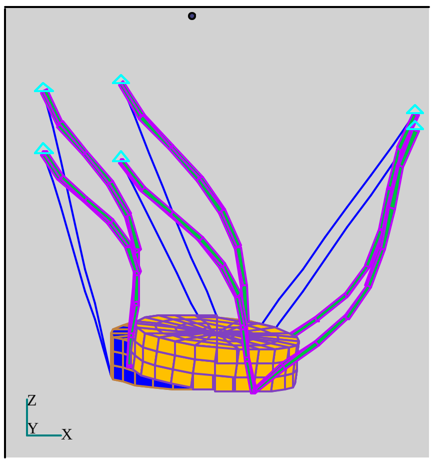
Secondary Metering Structure



	Tripod	Quadrupod	Cross-Braced Quadrupod	Hexapod truss with pinned ends	Hexapod truss with fixed ends	Octopod truss with pinned ends	Octopod truss with fixed ends	Curved leg hexapod	Hubble style (indirect support)	
# legs	3	4	4	6	6	8	8	6	4	ea
outside diameter	112	102	67	48	23	48	24	38	18	mm
wall thickness	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.0	mm
obscuration	8.6	10.4	6.8	7.3	3.5	9.8	4.9	8.2	1.8	%
interference spikes	6	4	4	4	6	4	4	0	4	ea
lowest violin mode	197	180	?	36	35	36	35	59	84	Hz
lowest global mode	35	35	34	56	35	?	39	35	35	Hz
mass of composite	6.4	7.7	8.9	5.5	2.6	7.3	5.2	4.5	12.1	kg
mass of fittings	39.7	41.3	16.1	8.5	1.4	11.3	1.8	4.6	10.1	kg
total mass of metering structure	46.1	49.0	25.0	14.0	4.0	18.6	7.0	9.1	22.2	kg

Tertiary Metering Structure

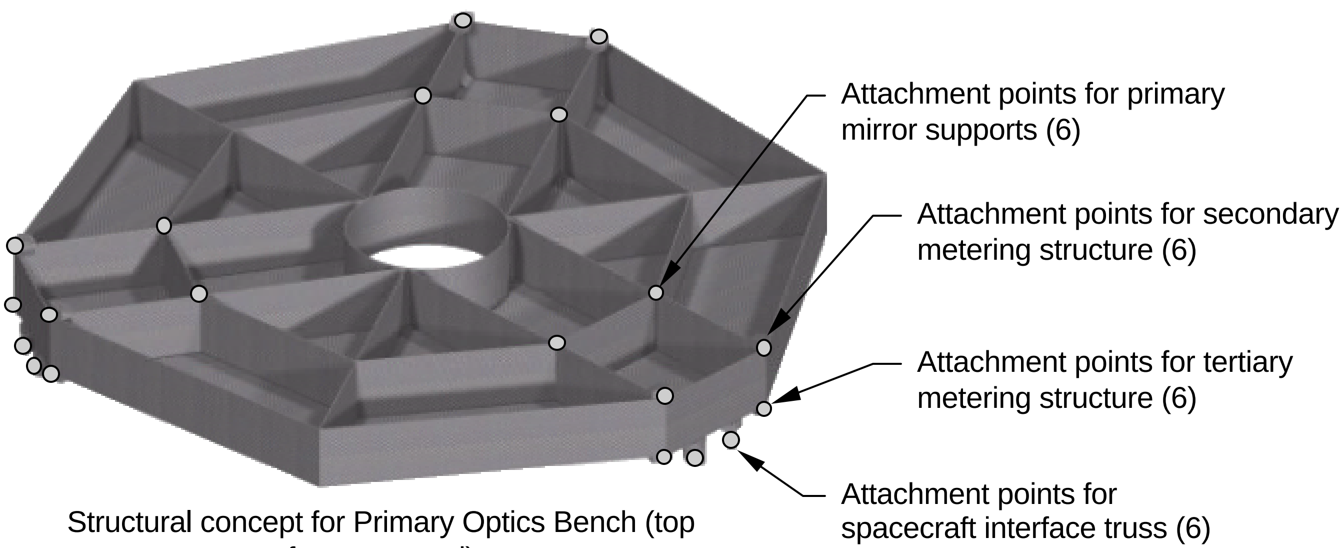
- **Key requirements:**
  - — Dimensional stability
  - — 35 Hz minimum fundamental frequency
- **Easier design problem than secondary metering structure**
  - — Overall dimensions much smaller than secondary metering truss
  - — No obscuration concerns
  - — Use strut design from secondary metering structure (cost effective)



Lowest global mode of tertiary metering truss: 110Hz

Primary Optics Bench

- **Key requirements and issues**
  - — **Dimensional stability**
  - — **Stresses (supports ~600 kg of instruments and mirror)**
  - — **High stiffness**
- **Baseline technology**
  - — **Bonded eggcrate construction from flat laminates**
  - — **Attachment points for secondary and tertiary metering trusses, spacecraft interface, and primary mirror close to one another (short and direct load paths)**



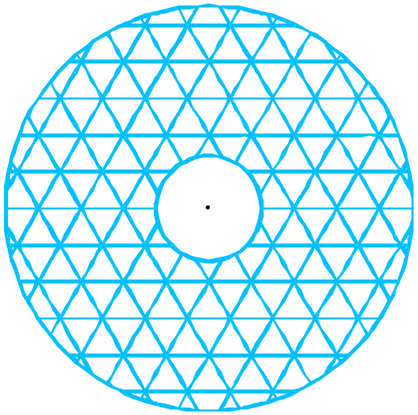
Structural concept for Primary Optics Bench (top face removed)

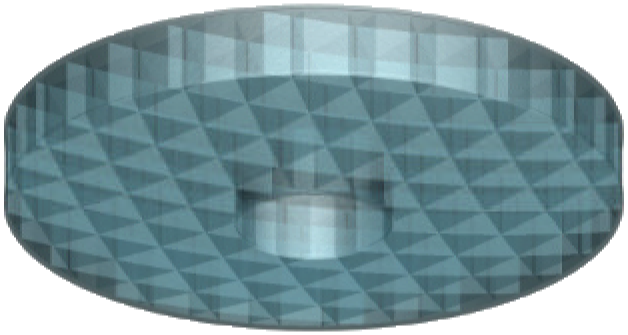
Telescope: Status

- **Mirror materials assessment begun**
  - —solid, ribbed, honeycomb beryllium "HIP"
  - —honeycomb silica, fusion or frit bonded
  - —borosilicate glass honeycomb, fusion bonded
  - —Corning ULE glass honeycomb, waterjet core + face sheets
  - —Schott Zerodur composite, weight relieved

Primary Mirror Substrate

- **Key requirements and issues**
  - — Dimensional stability over time
  - — Dimensional stability in thermal gradient
  - — High specific stiffness (1g sag, acoustic response)
  - — Stresses during launch
  - — Design of supports
- **Baseline technology**
  - — Multi-piece, fusion bonded, with egg-crate core
  - — Meniscus shaped
  - — Triangular core cells
- **Alternate technology**
  - — Core casting, waterjet relieved
  - — Face sheets, fusion bonded
- **Material**
  - — Baseline = ULE Glass (Corning)
  - — Alternate = Schott Zerodur

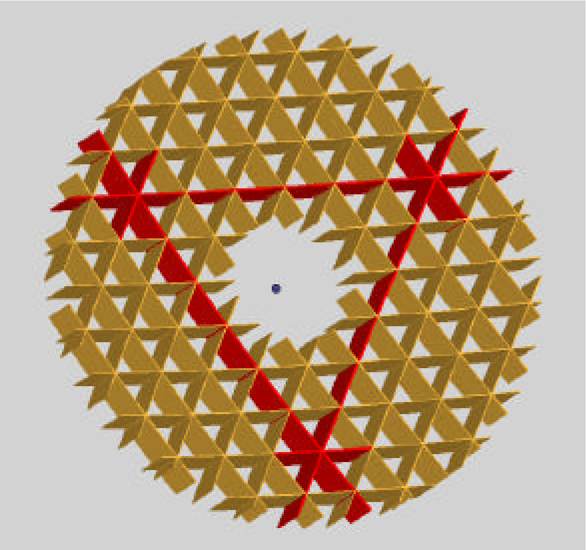




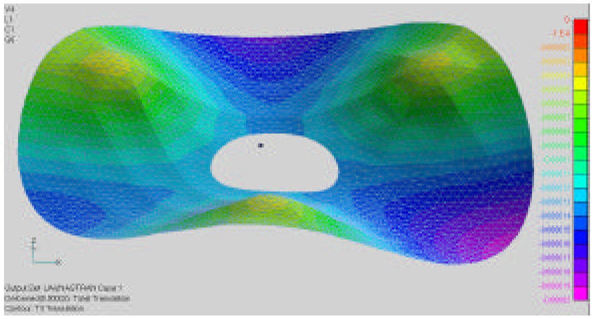
Initial design for primary mirror substrate: 334 kg

Primary Mirror Substrate

- Stresses from pseudo-static launch load factors
  - 6.5g axial, 0.5g transverse
  - 3-point supports
- Baseline
  - Face sheets (12 mm)
  - Locally thickened web walls (10 mm)
  - Thicker outer ring (8 mm)
- Mass (330 kg)
- Fundamental mode 360 Hz
- Conclusions
  - 80% lightweighted design is workable
  - 3 pt support *may* be usable for launch
  - Vertical axis airbag support required for figuring



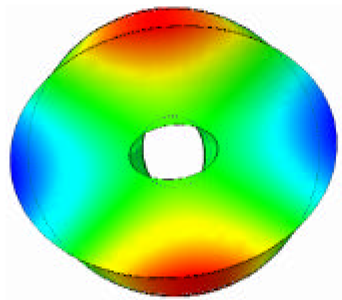
Design with locally thicker web plates
Standard web thickness = 5 mm (orange)
Thickened plates = 10 mm (red)



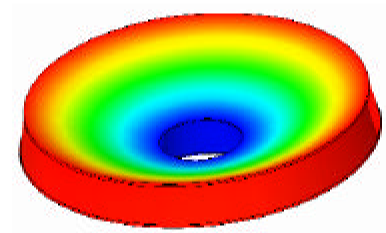
Deformations of mirror top face under pseudo-static launch loads: peak deflection = 20 μm

Primary Mirror Substrate

- **Free-free modes**

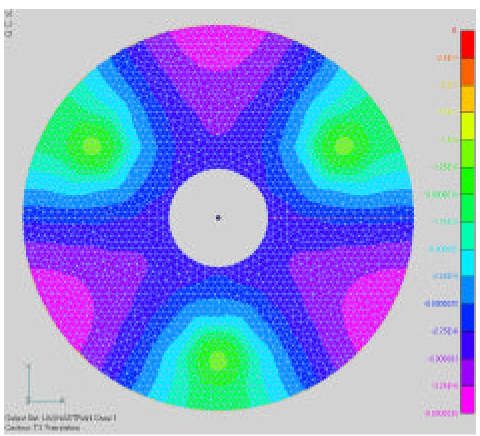


Fundamental mode: 360 Hz

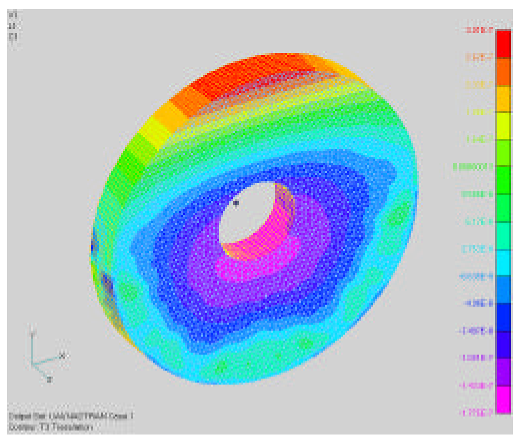


Second mode: 566 Hz

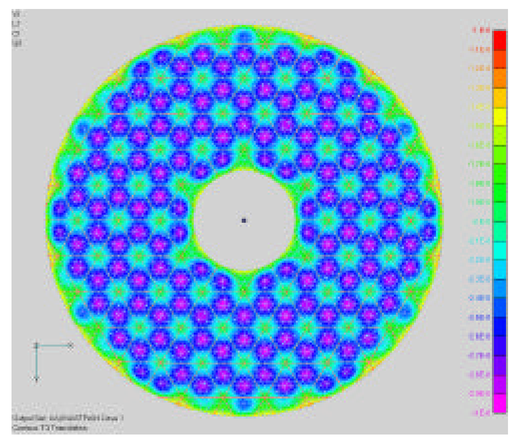
- **Sag during 1g figuring**
  - — **Sag is too large (>0.1mm) on simple supports (3 pt vertical, strap horizontal)**
  - — **Will likely require vertical axis figuring on airbag supports**



1g sag on 3pt support
vertical axis
P-P Z deflection = 2.3 µm



1g sag in 180º strap support
horizontal axis
P-P Z deflection = 0.5 µm



1g front face ripple on perfect
back-side support
P-P Z deflection = 0.018 µm

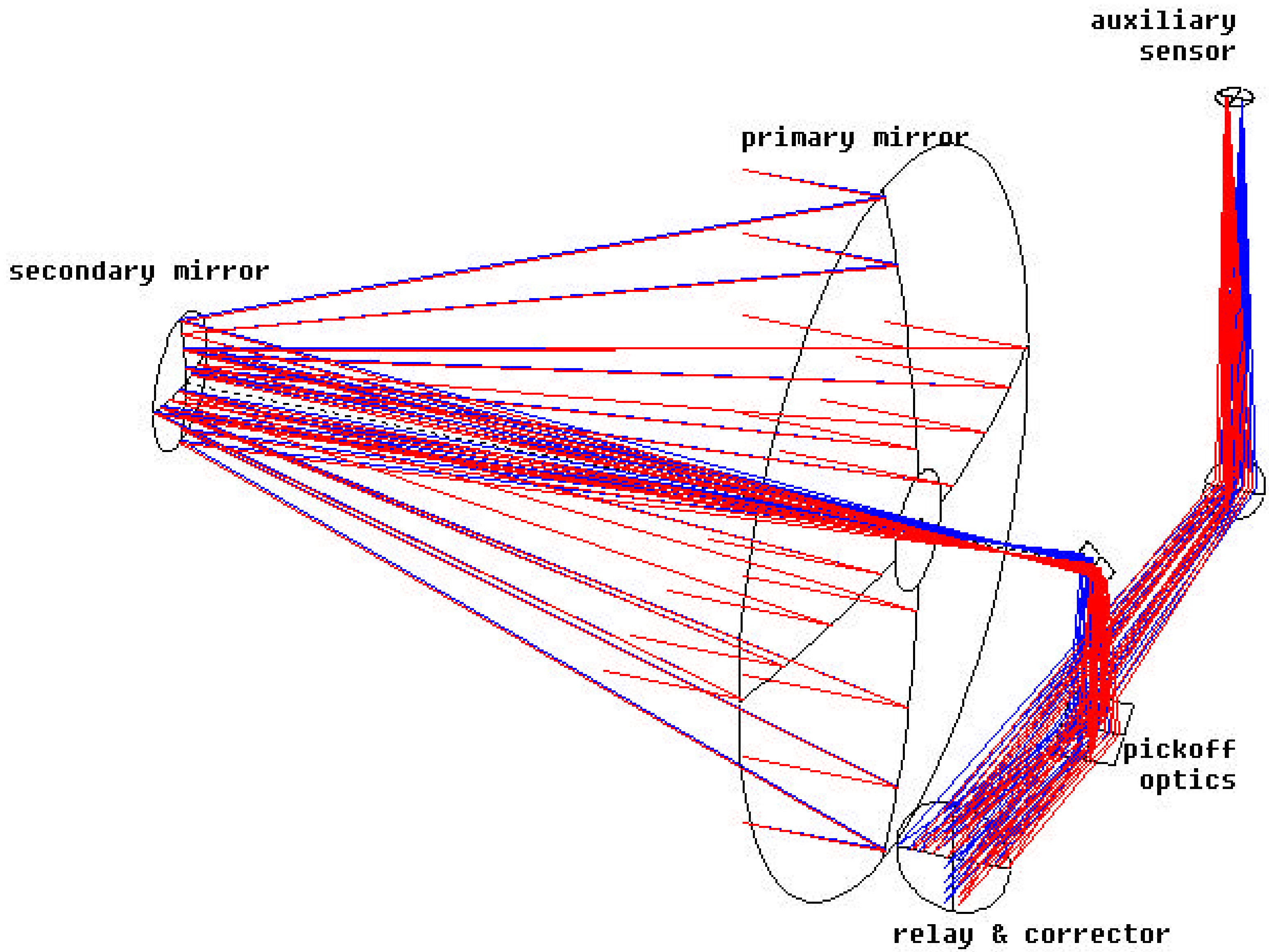
Telescope: Status

- **Fabrication and test plan assessment begun**
  - —earliest possible fab start for PM; figuring
  - —PM test & evaluation drives SM, TM
  - —Test sequence follows completion of each element
  - —Test sequence partly depends on availability of fixtures
  - —details to be defined partly by specific vendor proposals

Telescope: Status

- 13 On-orbit mechanical adjustments is minimum set
  - focussing
  - collimation
  - centering
  - alignment
  - hexapod concept for SM, TM, FF gives 18 adjustments; redundancy
- Focussing & alignment procedure: least squares optimization
  - will be developed & tested during R&D phase
- Filter wheel concept explored
  - stack of wheels, six filters per wheel, located near TM beam waist
- Auxiliary optics requirements (tracking, WNIR, spectrometers)
  - can deliver required light to specific instrument locations
  - pickoff mirrors located near cassegrain focus
  - could alternately deliver light to an integrated instrument package

Telescope: Auxiliary Optics Pickoffs



Telescope: Status

- Sensitivity & Tolerance Analysis has begun
- Requirements Document has been outlined
- Buy not Build
- Interface Specifications will begin in R&D Phase
  - Optical interfaces
  - Mechanical interfaces
  - Thermal interfaces
  - Electrical interfaces
- Trade Studies Identified for R&D Phase
  - Warm optics vs Cold optics
  - FIDO integrated focal plane vs separated instrument focal planes
  - Low-CTE metering structure vs Constant-T structure
  - Protoflight vs Prototype + Flight metering structures
- Trade Studies Identified for Preliminary Design Phase
  - Mirror materials: ULE vs Zerodur
  - Gravity unloading plan: mechanical vs hydraulic vs pneumatic
  - Exact aperture: cost & schedule vs aperture
  - Detailed test & acceptance sequence

Telescope: Status

- **Risks Identified**
  - — Mirror fab/test risks
    - Far less demanding than HST: we are NIR not NUV
    - “Easy” testing: primary is ellipsoid, not hyperboloid
  - — Mechanical structural risks
  - — End to end performance risks
    - “Easy” thermal environment: HEO has few/no eclipses
  - — Disturbances on orbit
    - Far less demanding than HST: no twang, few/no eclipses
  - — Schedule risks: OTA is a long lead item!
  - — Error budget: fixturing, optical test equipment, etc
  - — Contamination control: materials & test plan
  - — Stray light control: management & test plan
  - — Optics spares & backups

Telescope: Technology Assessment

	SNAP OTA Technology Assessment	TRL	TRL	TRL
			-	
	Global Risks and Related Technology Issues	**1/1/01**	**10/2/02**	**9/3/03**
	Optical Design re. Wide Field Performance	3	6	6
	Performance Robustness, i.e. Alignment Sensitivity	7	7	7
	Stray Light and Performance Adequacy	3	6	6
	OTA Configuration and Interfaces	5	7	7
	Instrument Section Configuratio & Interfaces w/OTA	3	6	6
	Weight	7	7	7
	ULE Substrate Producibility and Weight	7	7	7
	Optical Fabrication, Metrology and Gravity Release	7	7	7
	Optical Coating (protected silver)	7	7	7
	Mounting, et al	7	7	7
Overall OTA Design				
	Mirror	7	7	7
	6 DoF Mounting	7	7	7
	Alignment Stability (Structure)	7	7	7
	Mirror incl. Cryo Null Figuring	7	7	7
	Mounting and Alignment	6	7	7
Primary Mirror				
	Beam Directing Flat(s)	7	7	7
	Filter Wheel Assembly	Insufficient requirements and configuratic		
Se	CFRP Materials Design and Fabrication	8	8	8
	SM Support Structure	No		
	Instrument Support Structure		problems	
	Integrating Structure			anticipated
	Jitter and Micro-Dynamics	6	6	6
Te	Alignment Stability (thermal)	6	8	8
	External Baffles	8	8	8
	Viewport Door	8	8	8
Other Aft-Section Optics				
	OTA Passive Alignment Stability	3	6	6
	OTA/Instrument Mounting Interface Stability	3	6	6
	PM Heater Control	8	8	8
Te	Cold Instrument Section	Insufficient requirements and configuratic		
	Dewar	5	5	5

Telescope: R&D Management

- Buy not Build
- Management objective: biddable Requirements Document
- Experienced team has been assembled
- Have already begun examining potential fab/test flows
- No need for high-risk “advanced” materials or processes
- Seek telescope concepts that are space proven
- Plan on selection of contractor with sufficient experience to bring successful delivery cost & schedule

Telescope: Summary

- **Pre-R&D**
  - — convert science drivers into telescope requirements
  - — reviewed existing optical telescope concepts
  - — developed annular-field TMA configuration
  - — preliminary materials assessment
  - — buy not build decision
  - — explored vendor capabilities
- **R&D Phase**
  - — trade studies
  - — risk assessments
  - — performance specifications & tolerance analysis
  - — develop conceptual design
  - — create draft ICDs
  - — develop preliminary cost & schedule ranges